Ripples in the Anterior Auditory Field and Inferior Colliculus of the Ferret

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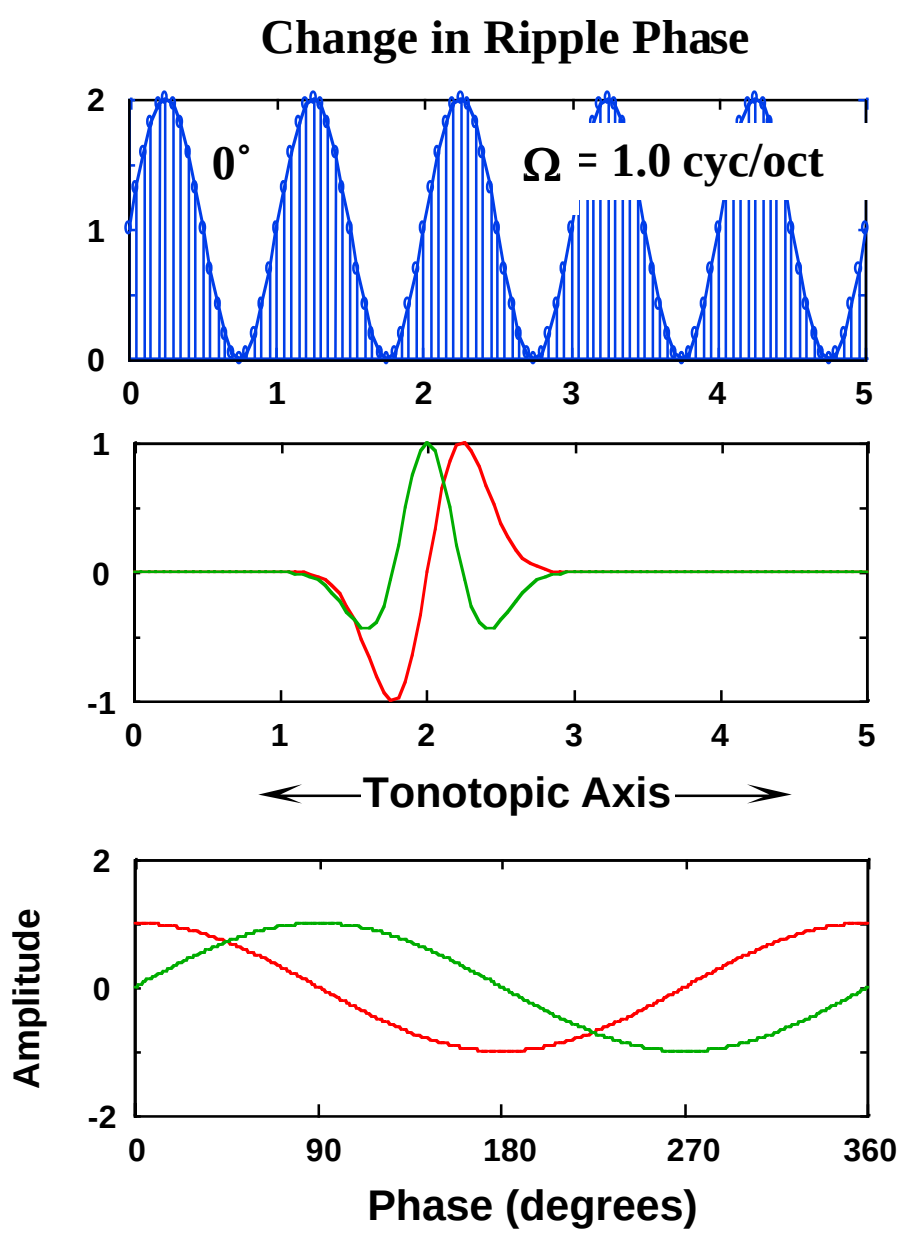
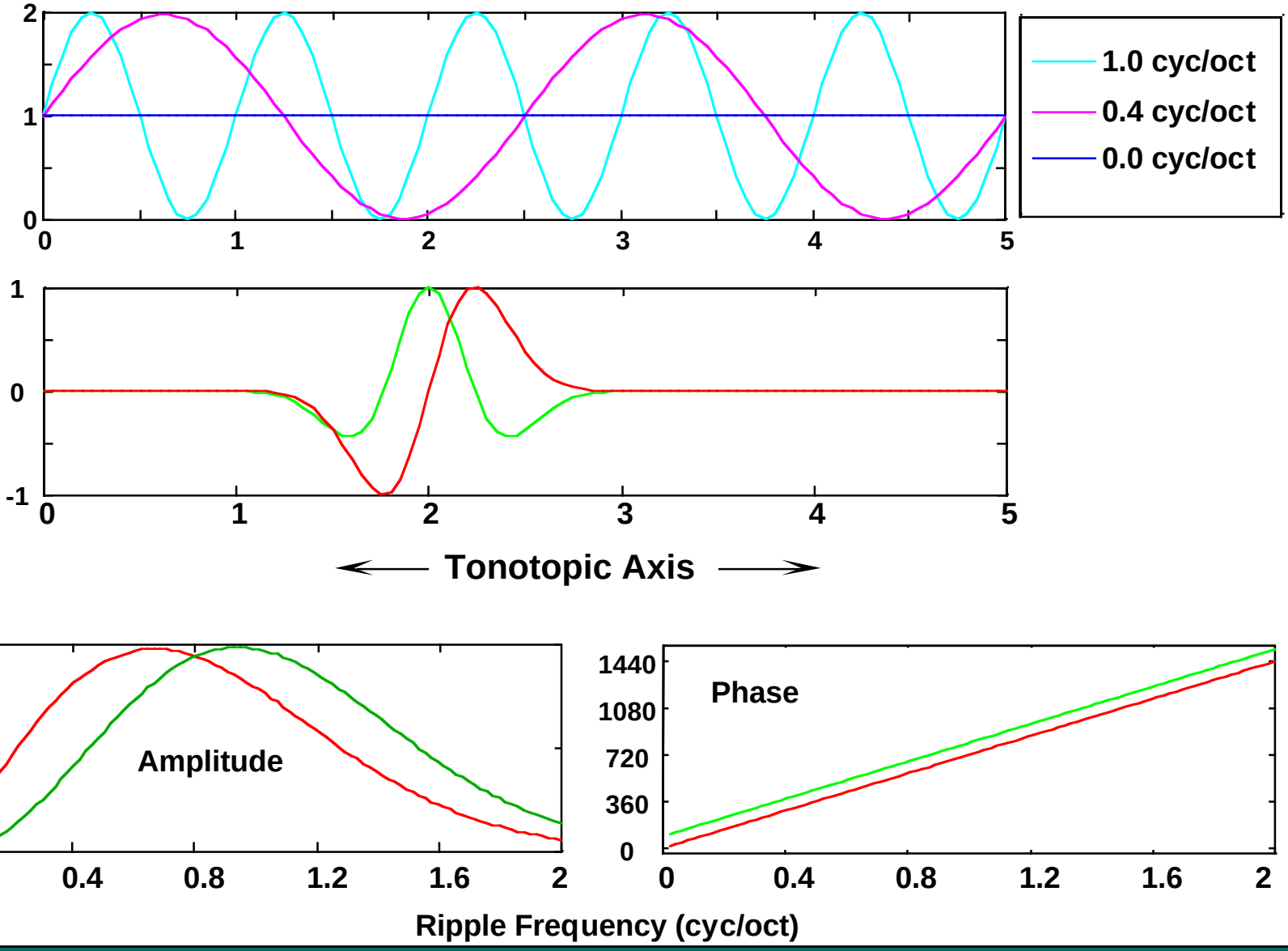
Methods

- Responses of single units in AI, anterior field (AAF), and Inferior Colliculus (IC) in the barbiturate-anaesthetized ferret were recorded with single tungsten electrodes. Data were collected from a total of 7, 5 and 11 (resp.) ferrets, each weighing between 1.5 - 2.1 kg.
- Surgery and Animal Preparation: The techniques involved in the surgery and preparation for recording are described in detail in Shamma et al. (1993). The ferrets were anesthetized with pentobarbital sodium (40 mg/kg IP) and maintained in an areflexic state using a continuous IV infusion of pentobarbital (~ 5 mg/kg/hr) diluted with dextrose-electrolyte solution for metabolic stability. Data collection typically lasted 60-70 hours.
- Recording Procedures: Single-unit action potentials were recorded using glass-insulated tungsten microelectrodes with 5 to 6 MΩ impedances. The recorded signals were led through amplifiers and filters. Depending on the paradigm, a stimulus was presented every few seconds, and raster plots with 1ms time resolution were produced.
- In AI, recordings were typically made at depths of 300 - 600 µm (layers III and IV). In AAF, electrode penetrations were made parallel to the depth of the suprasylvian sulcus (SSS), approximately 0.5 mm caudal of the sulcus so that cortical layers III and/or IV were reached. IC was exposed by removal of (visual) cortex, and electrodes were lowered until ICC was reached, following standard criteria.


Change in Ripple Phase
0°
Ω = 1.0 cyc/oct
2
1
0
0
1
2
3
4
5
1
0
-1
0
1
2
3
4
5
Tonotopic Axis
2
0
-2
Amplitude
0
90
180
270
360
Phase (degrees)

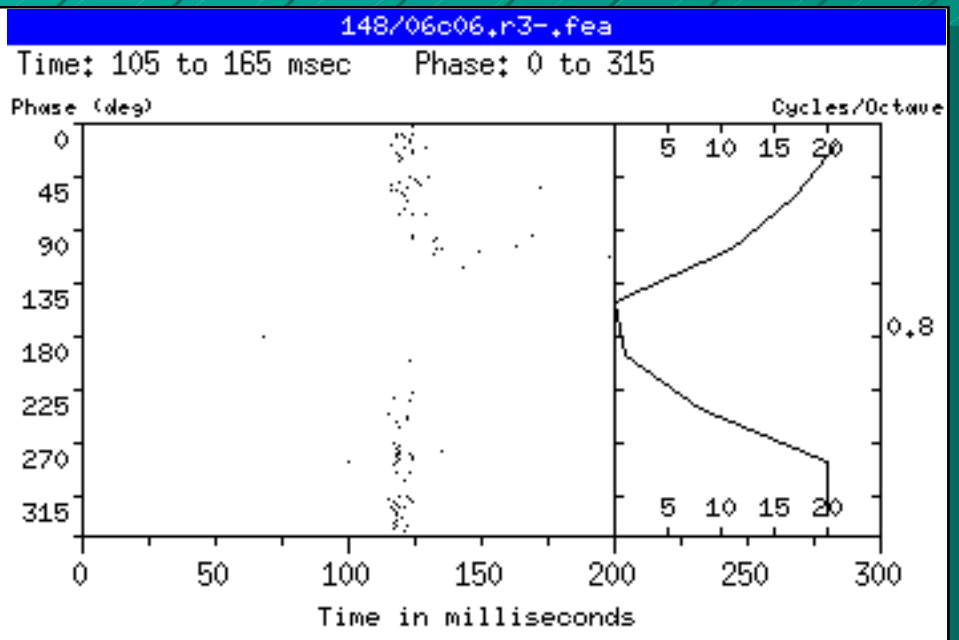
Measuring the Ripple Transfer Function

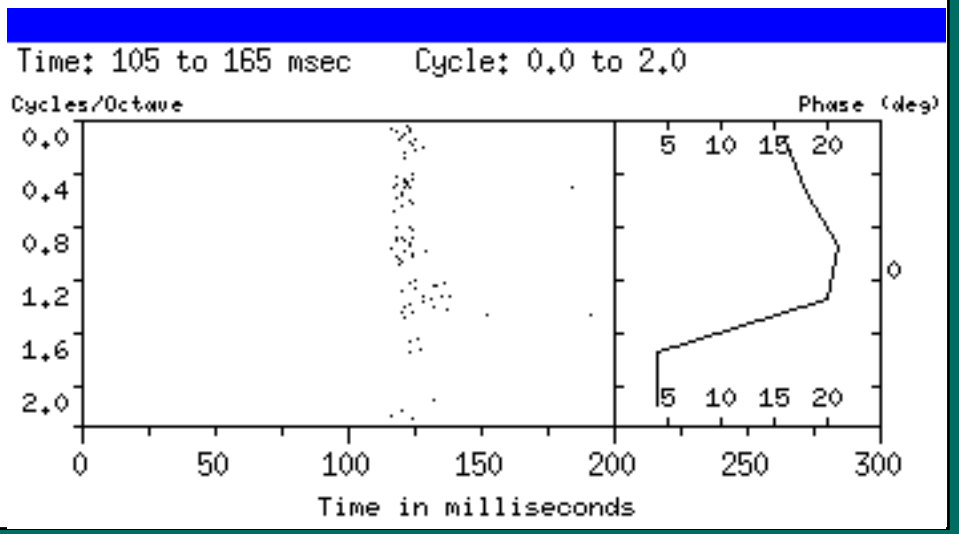


0.8 cycles/octave
at 8 different phases

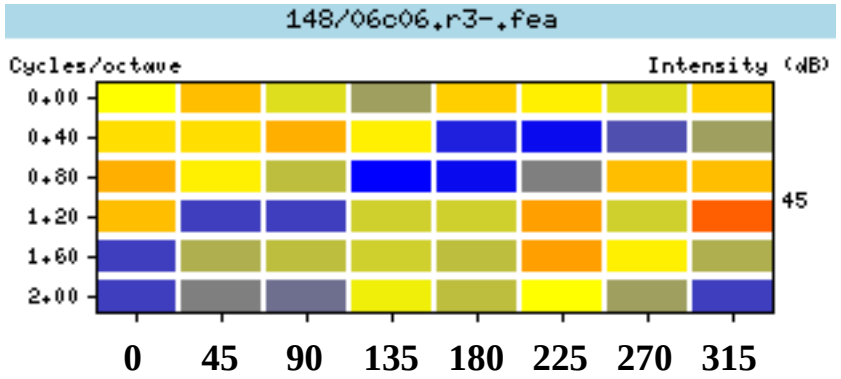
Stimulus onset: 100 ms
Stimulus offset: 150 ms

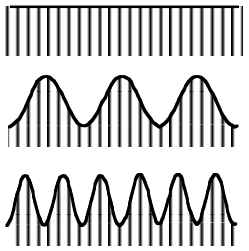
0 phase ripple at
6 different ripple freq.

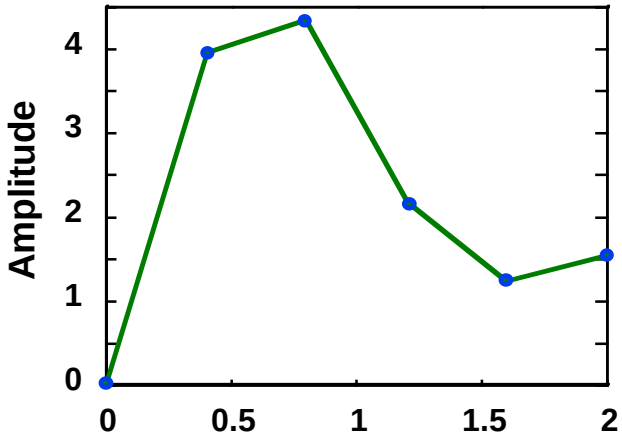


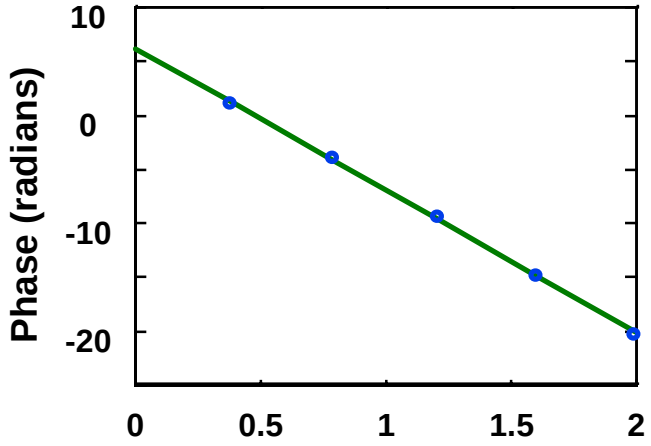


Tuning as a function of Ripple Frequency and Phase

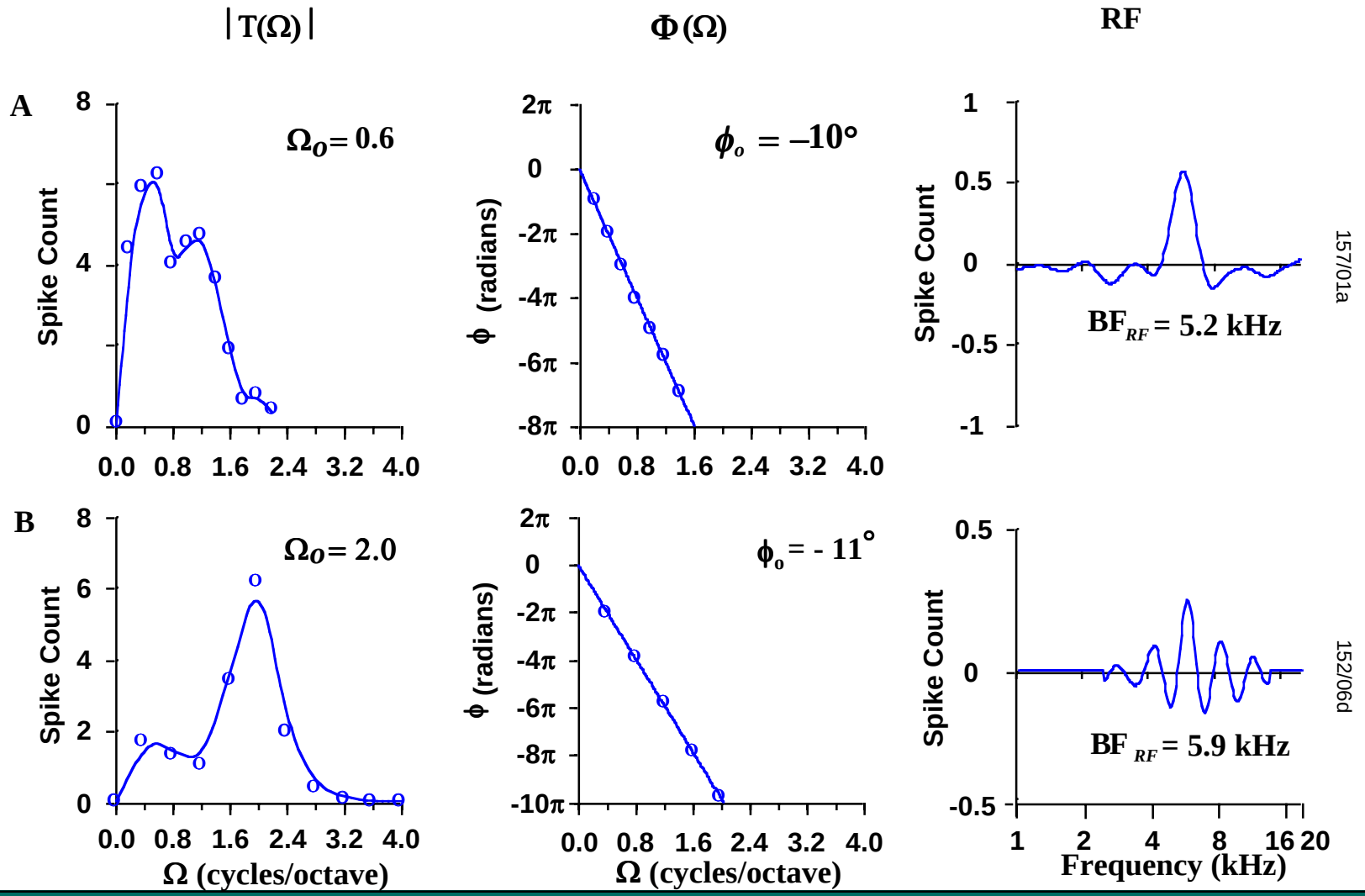




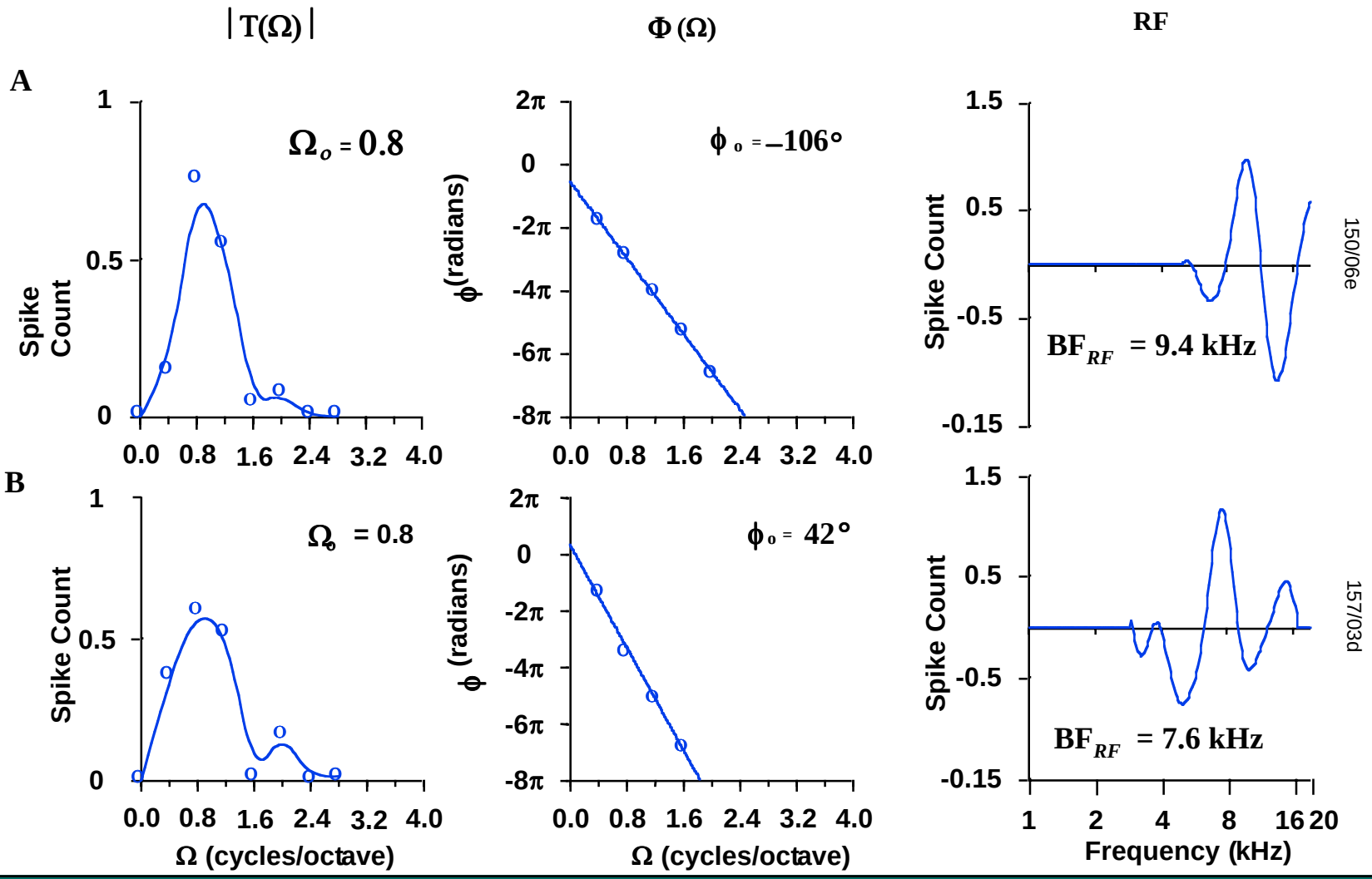




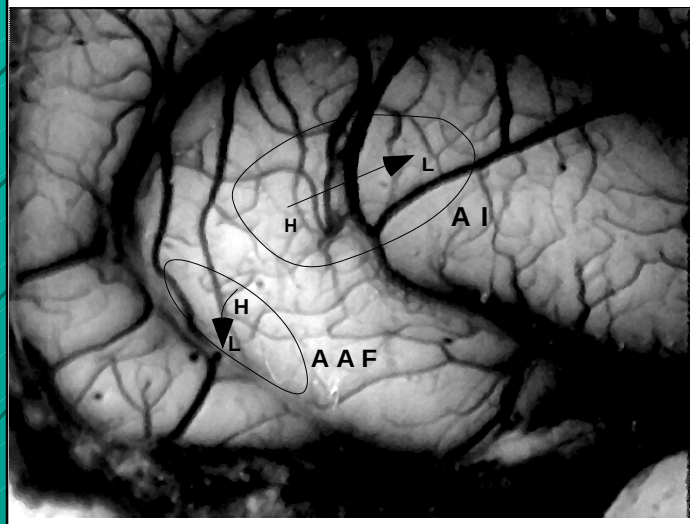
Response fields of varying bandwidth

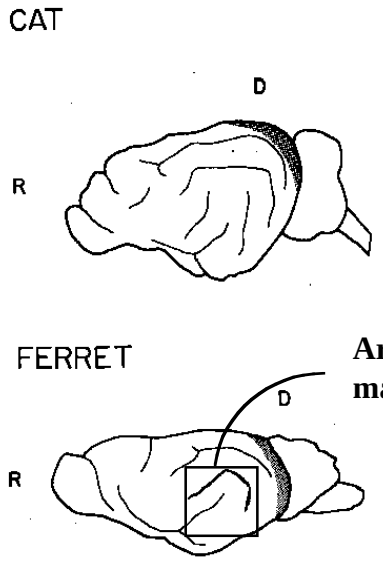


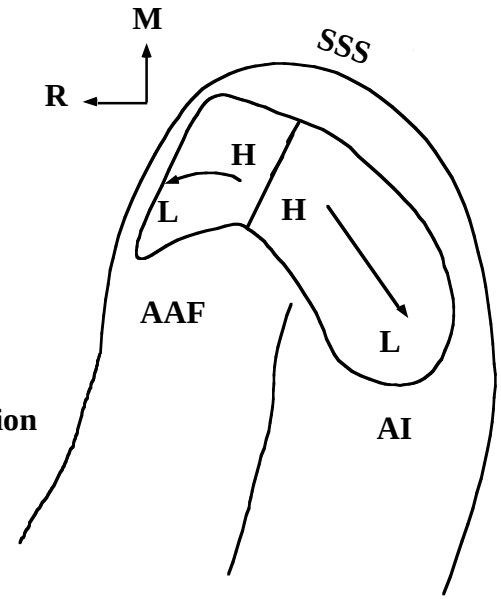
Response Fields with varying asymmetries



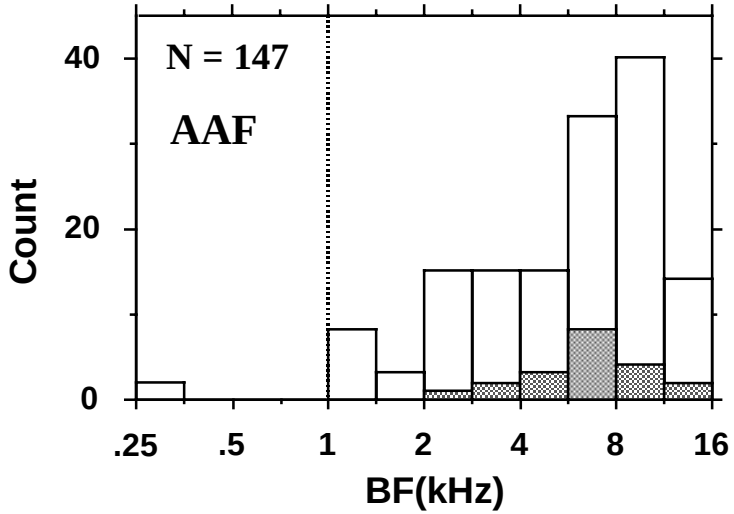
The Anterior Cortical Field

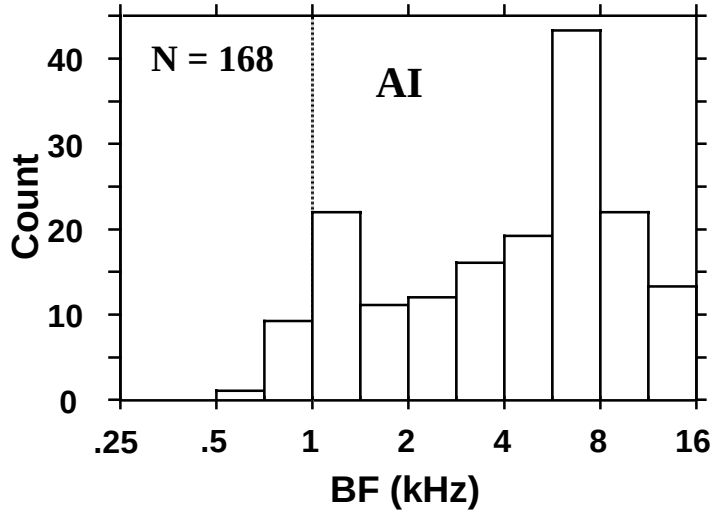


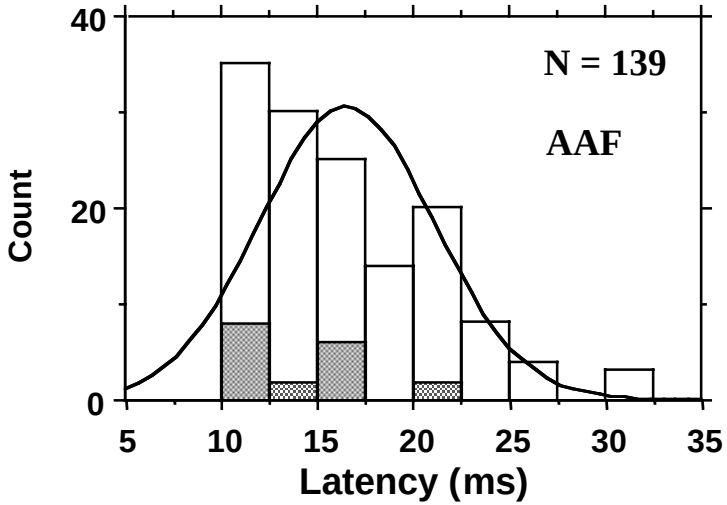


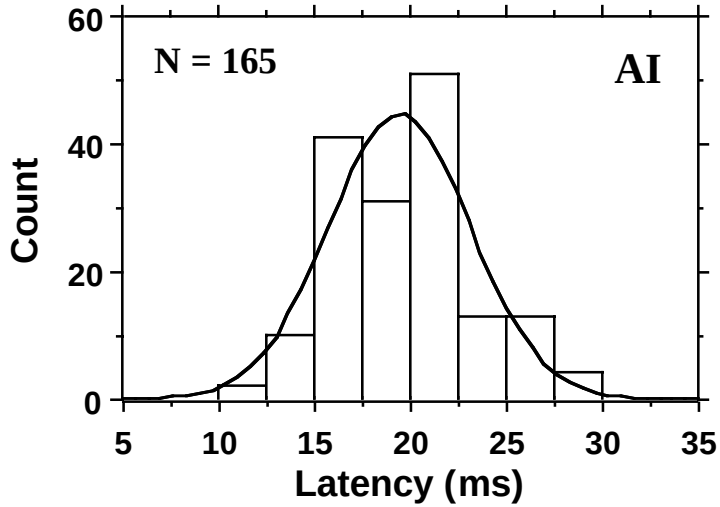


BF's and latencies are similar

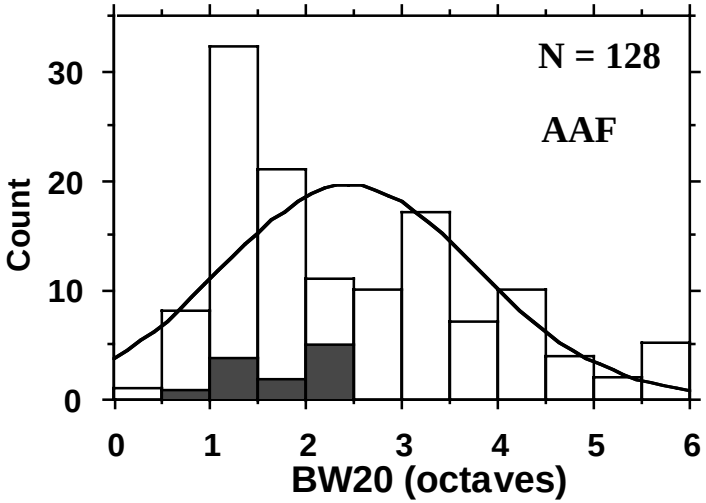


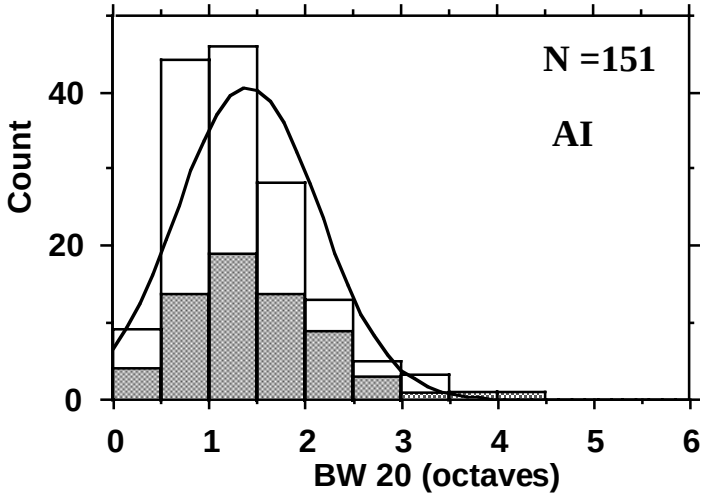


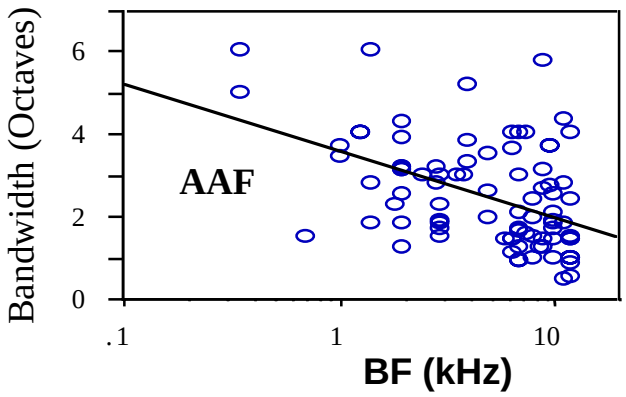


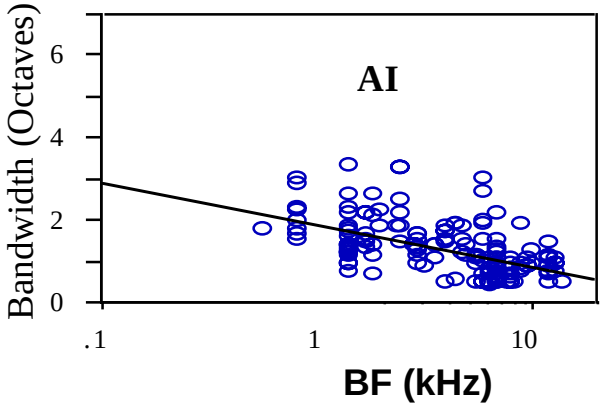


Bandwidths (BW20) are larger in AAF

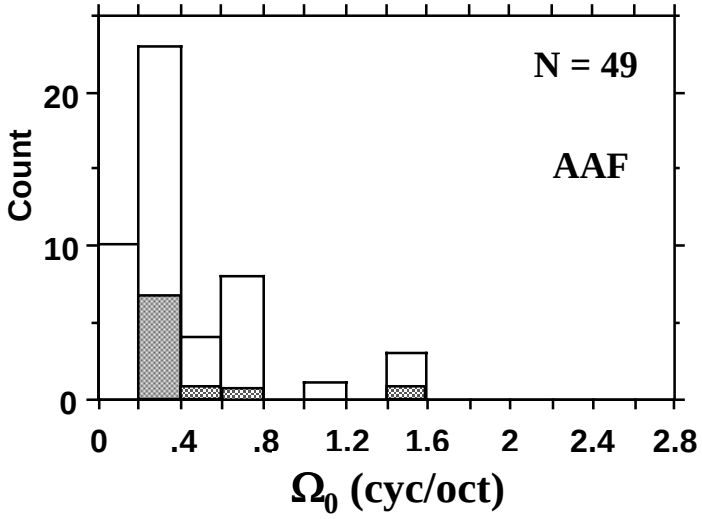






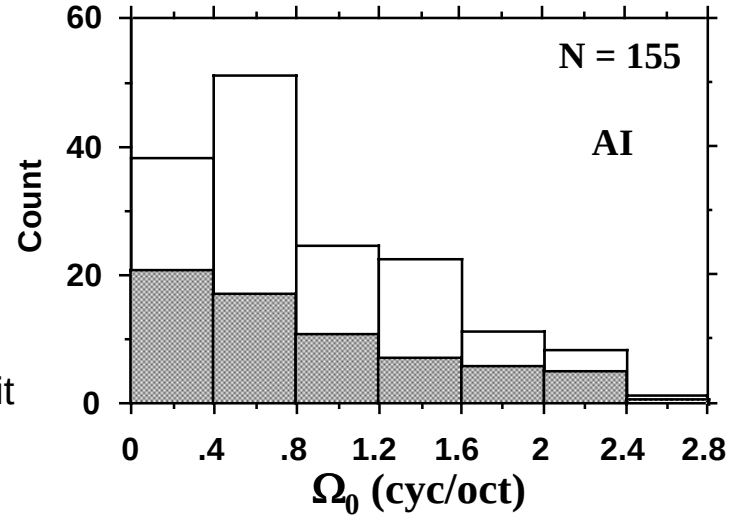


Tuning to Ripples tends to be lower in AAF

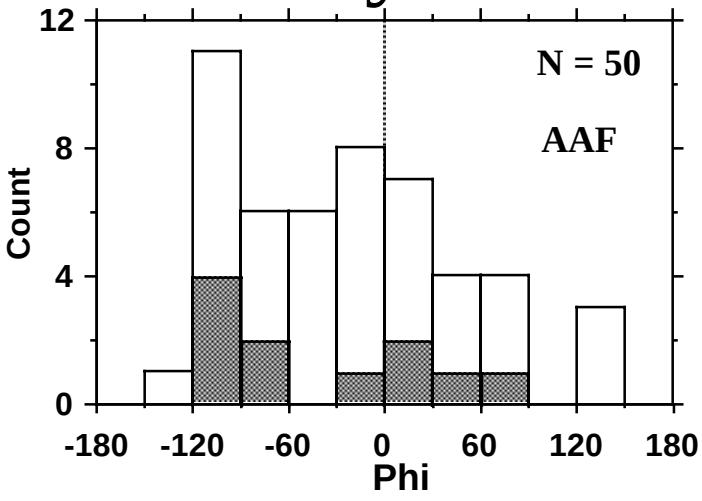


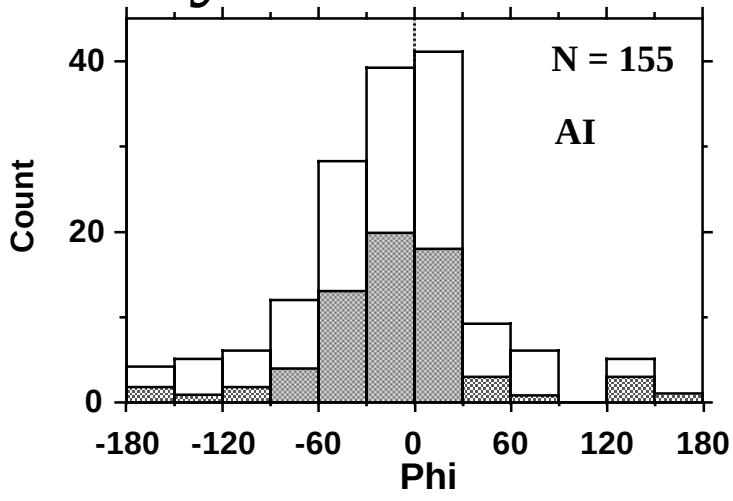
Ω_0 = Best Stationary Ripple Frequency (cyc/oct)

Single Unit
Cluster



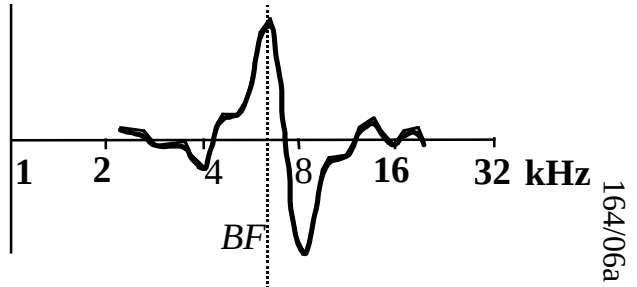
RF's asymmetries are evenly distributed



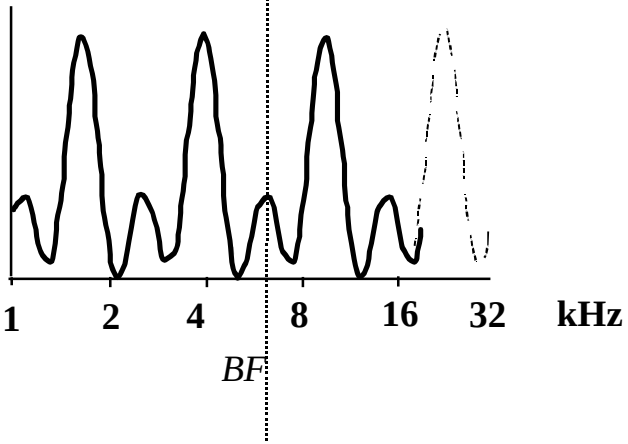


Predictions Using Stationary Ripples

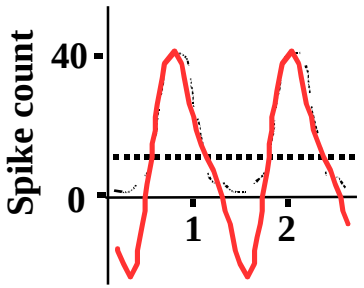
Response Field of Cell



Spectral Profile of stimulus



Response of Cell to Profile



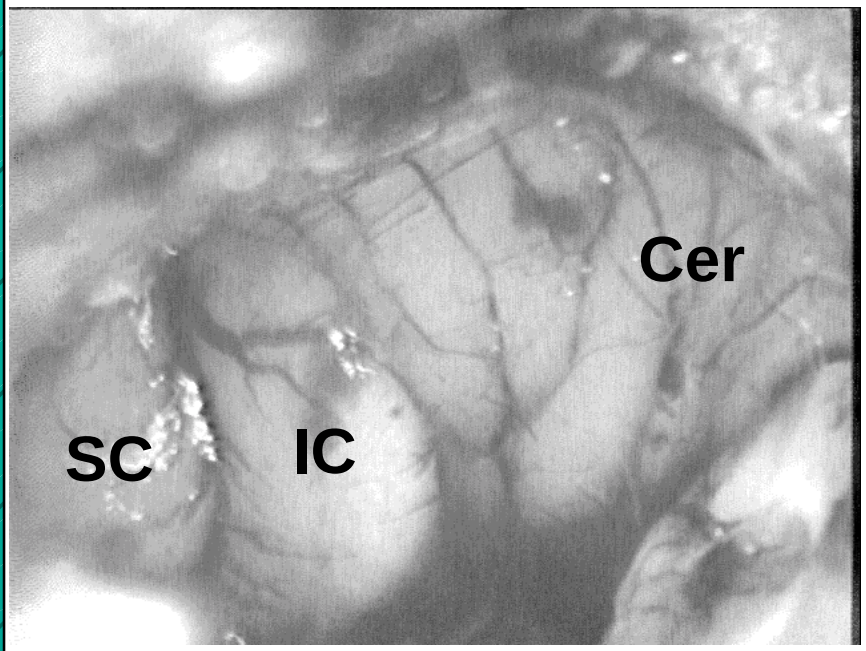
shift, δ (octaves)

Measured Response

Predicted Response

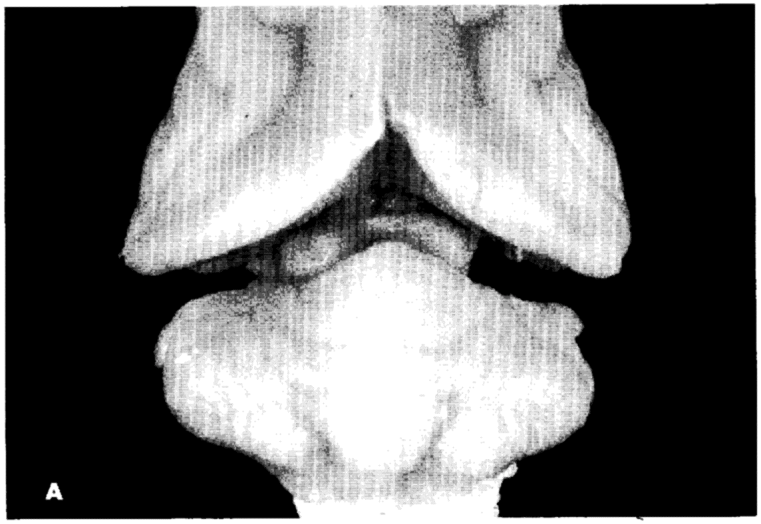
Response to flat spectrum

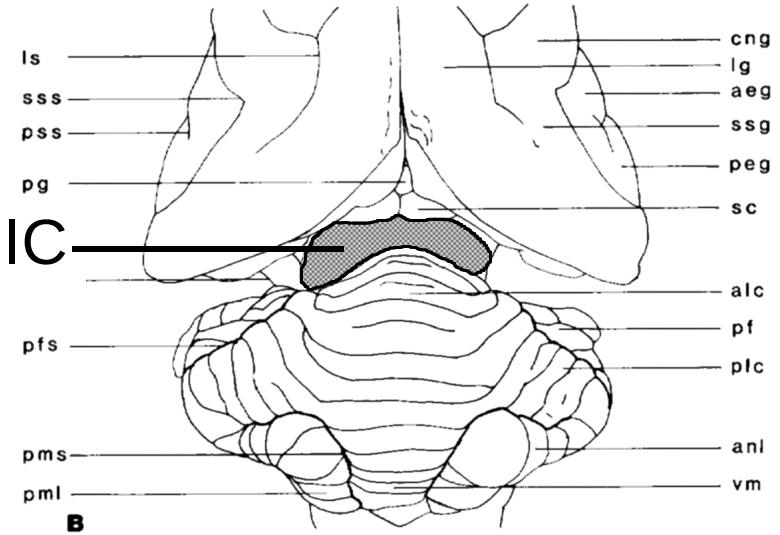
The Inferior Colliculus



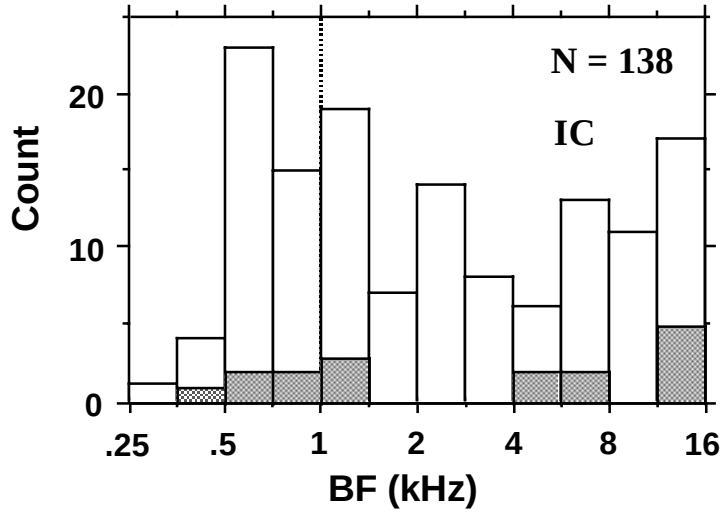
R

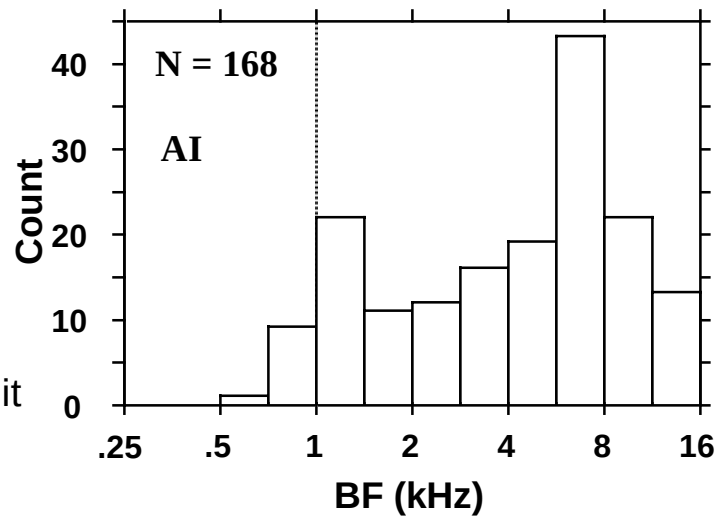
L

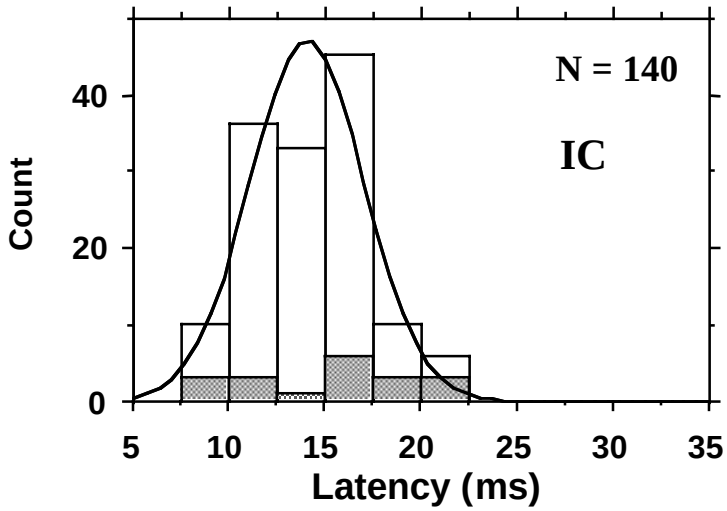


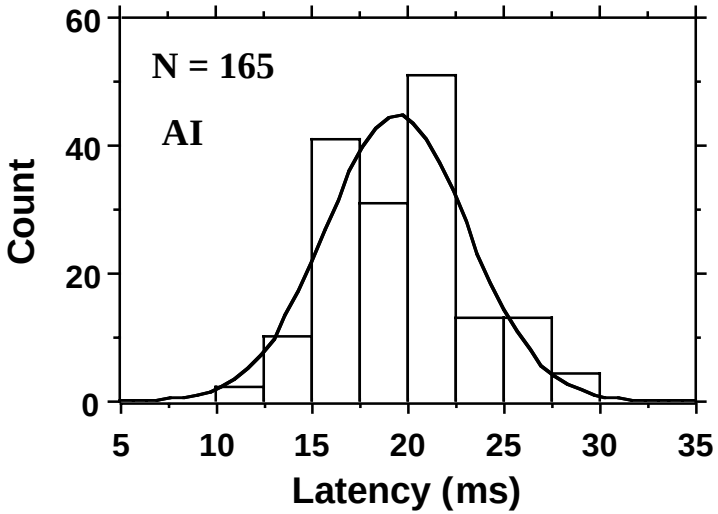


Of BF's and Latencies

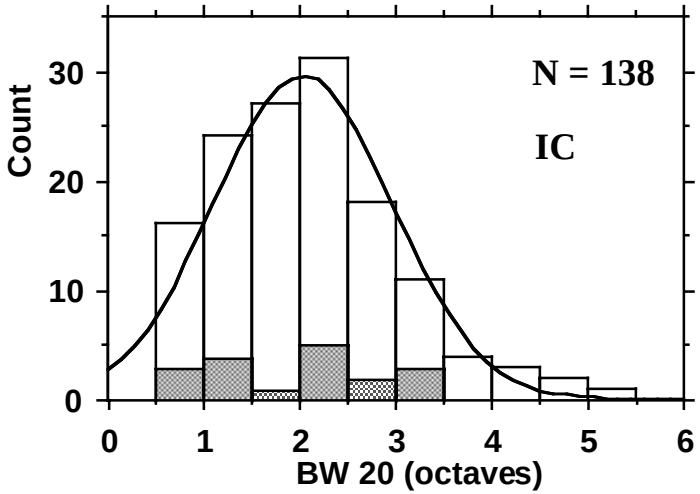


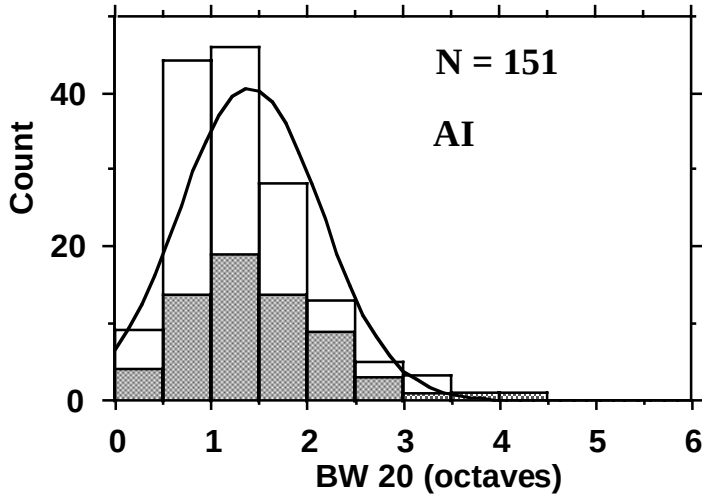


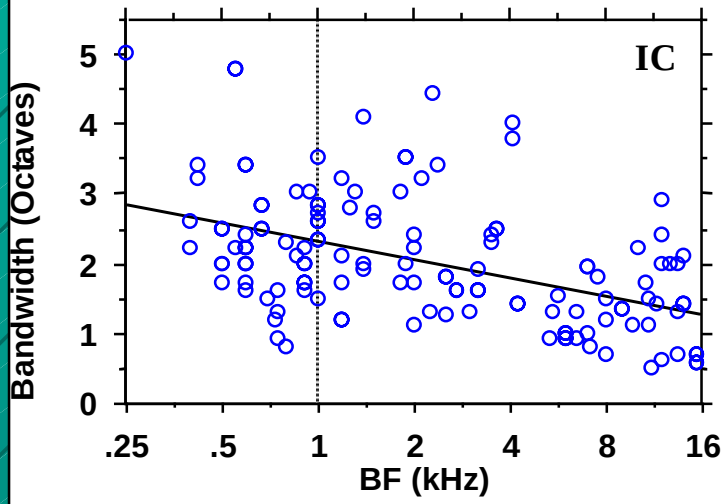


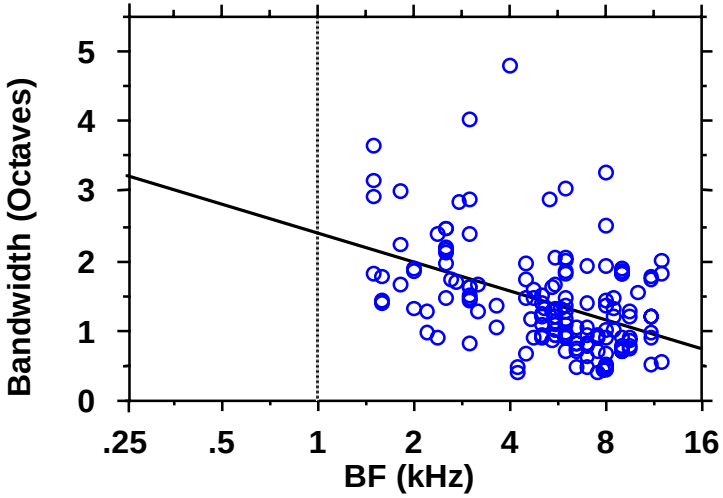


Bandwidths

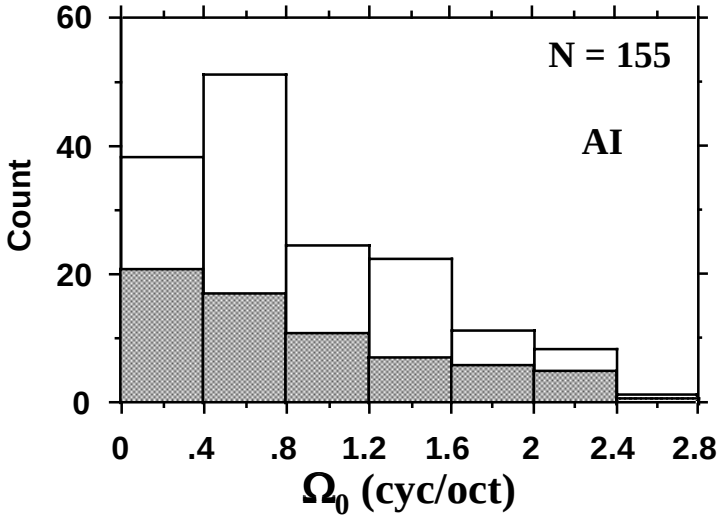

N = 138
IC
Count
BW 20 (octaves)

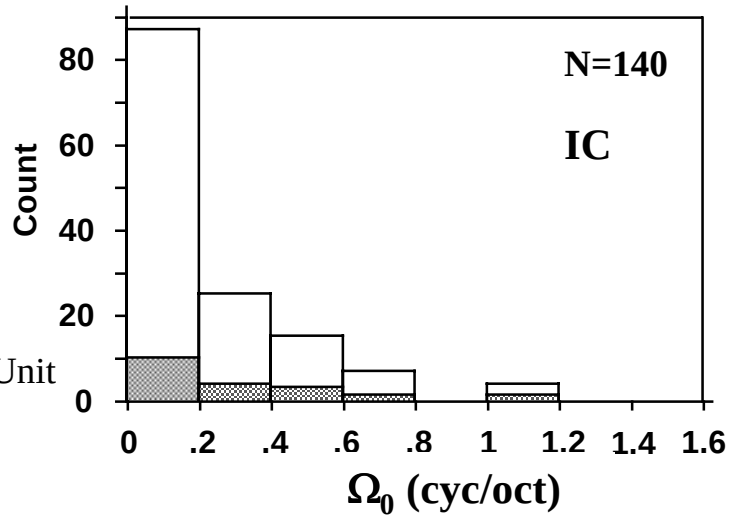

N = 151
AI
Count
BW 20 (octaves)


IC
Bandwidth (Octaves)
BF (kHz)

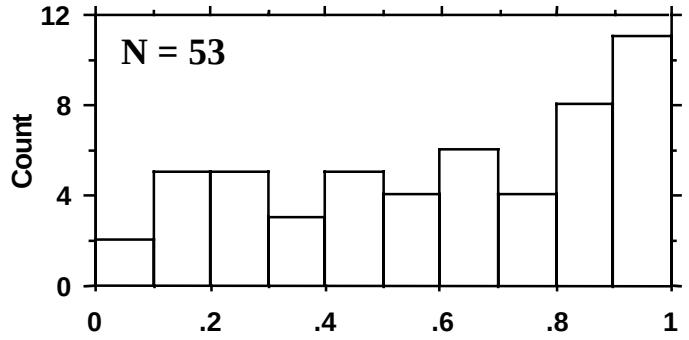

Bandwidth (Octaves)
BF (kHz)

Best Ripple Frequency





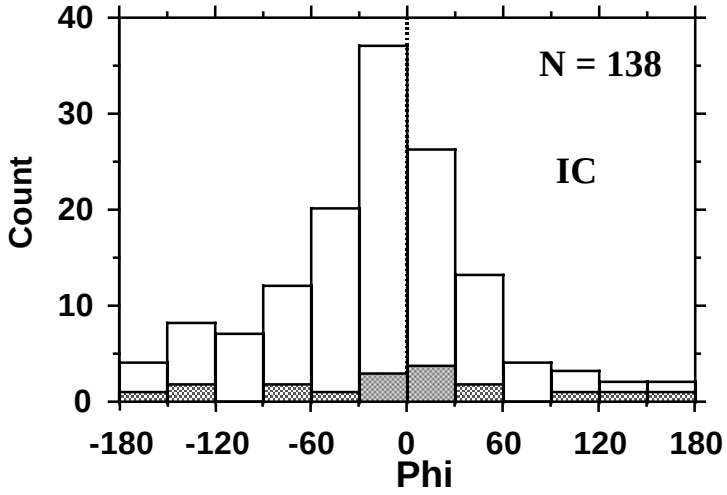
Single Unit
Cluster

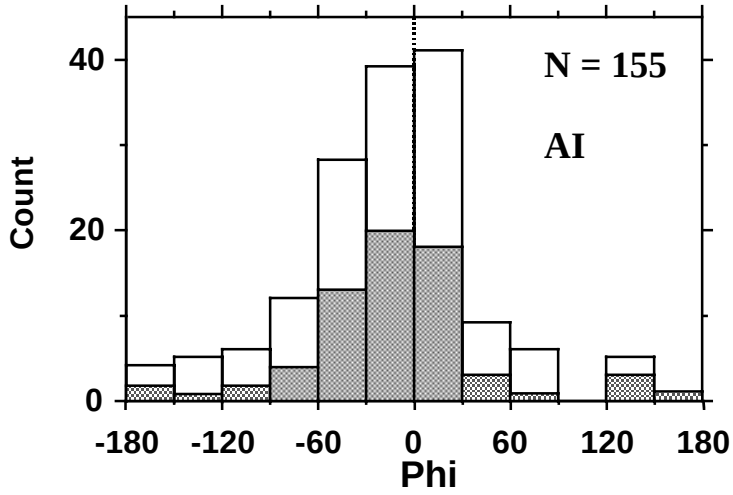


Tuning at .2 (c/0)/ Tuning at best ripple

Ω_0 = Best Ripple Frequency

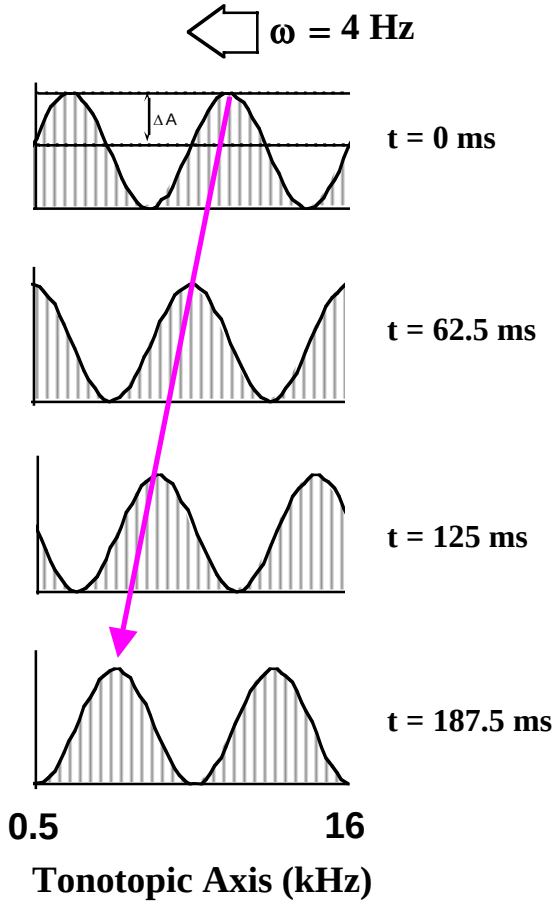
RF's are more symmetrical in IC

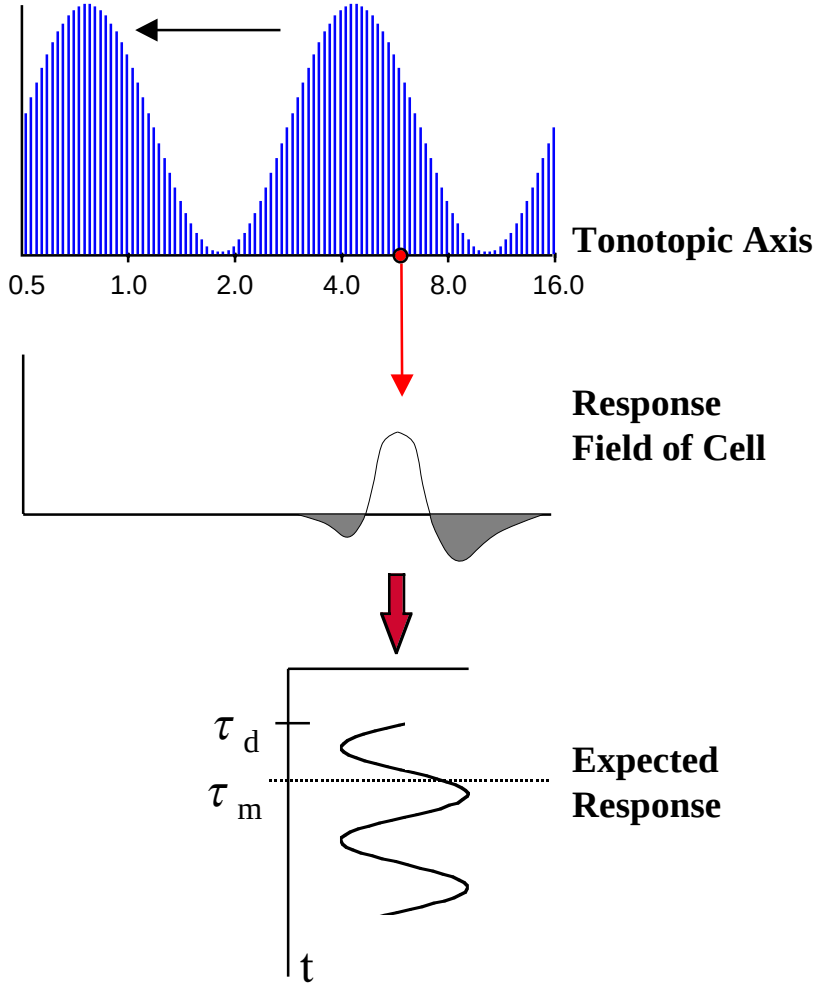




Single Unit
Cluster

Temporal properties: Moving Ripples

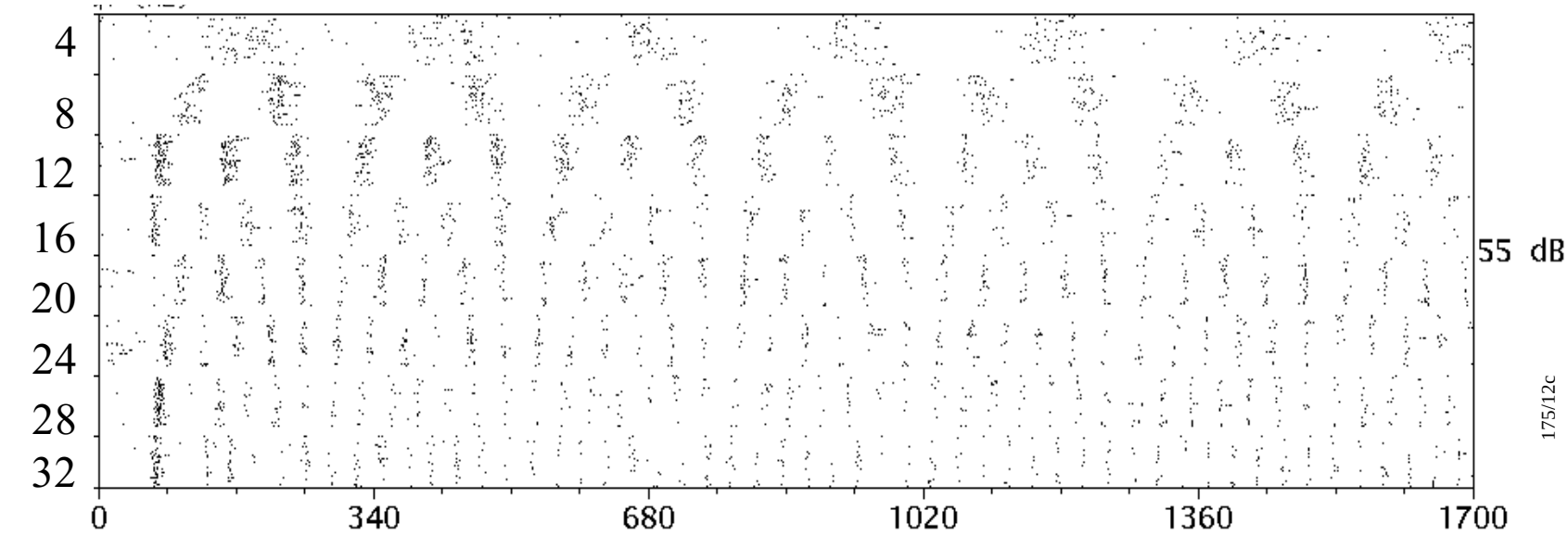




- Ω = ripple frequency in cycle/octaves
- ω = temporal frequency in Hz

Responses to Moving Ripples

Ripple Frequency is 0.4 cycles/oct

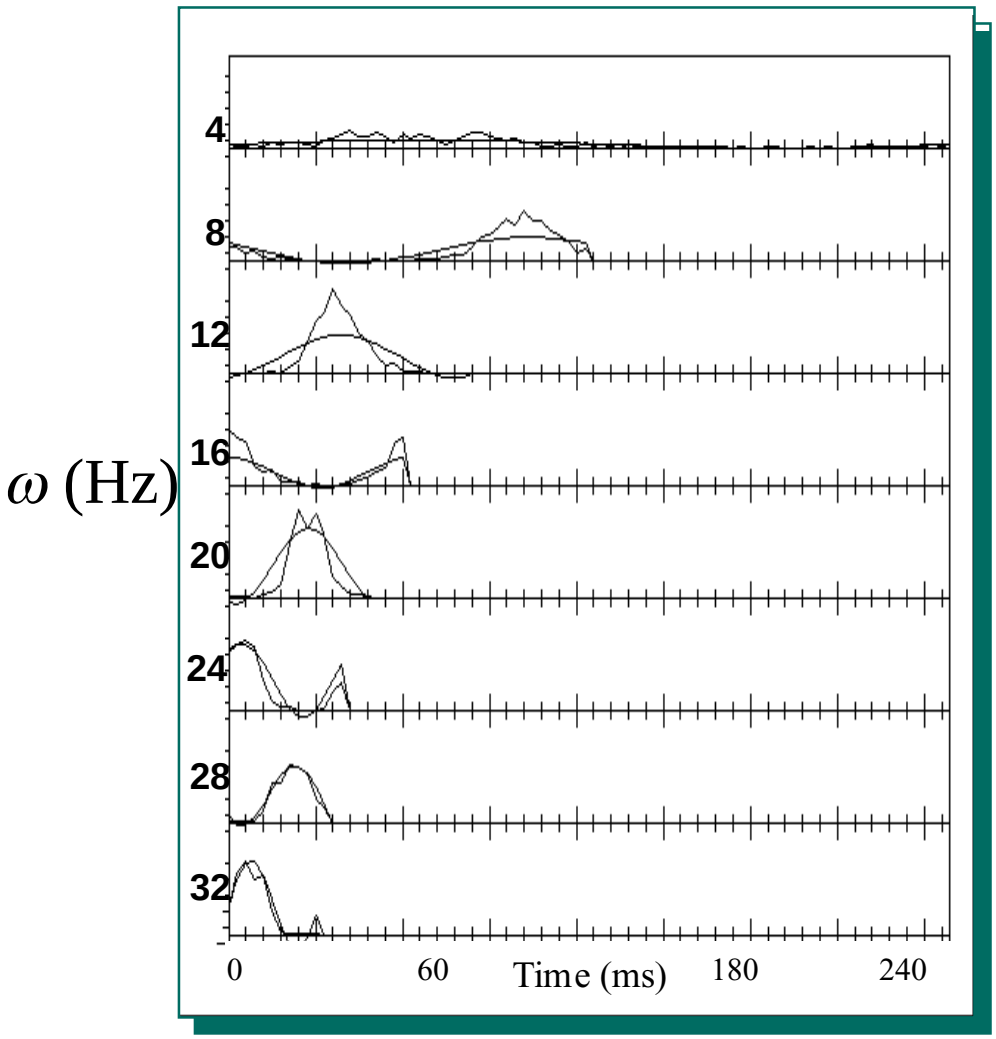


Ω = 0.4 cyc/oct

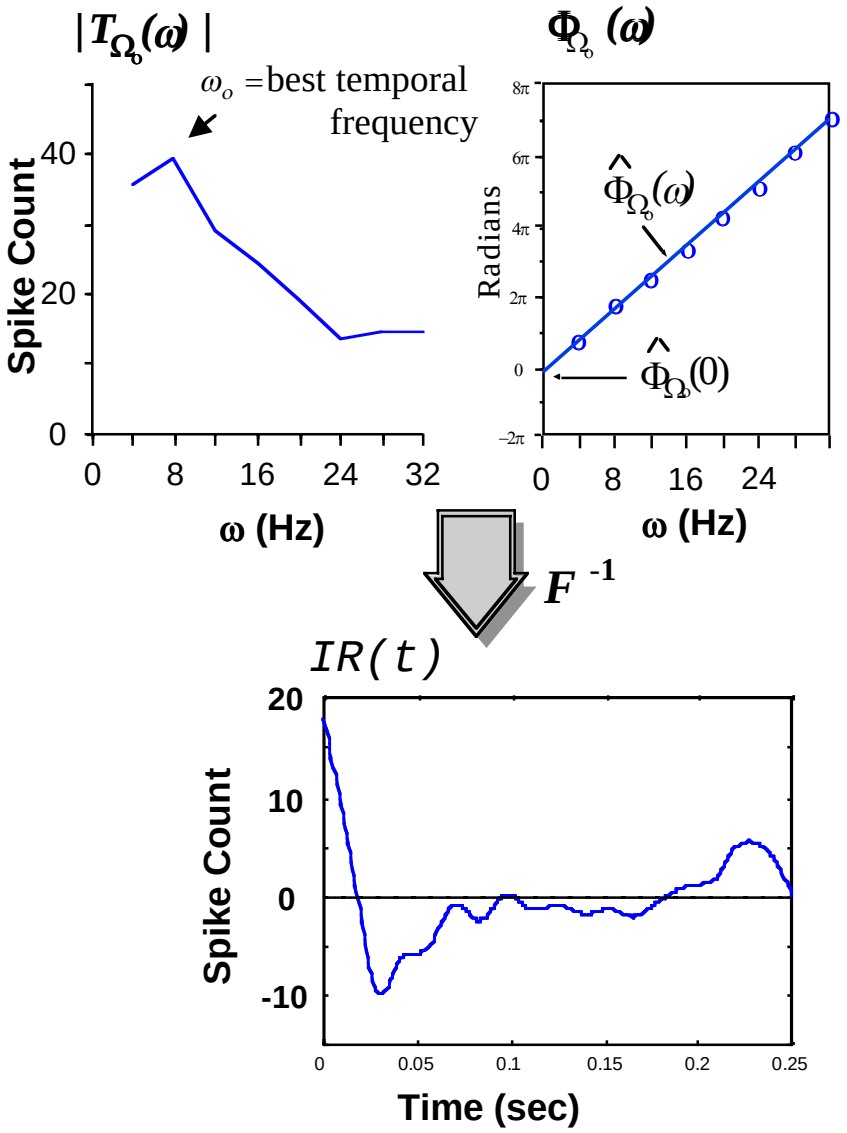
ω = 4 to 32 Hz

30 sweeps per ω

Step 1. From Spike Count to Period Histogram



Step 2. Magnitude and Phase of Best Fit

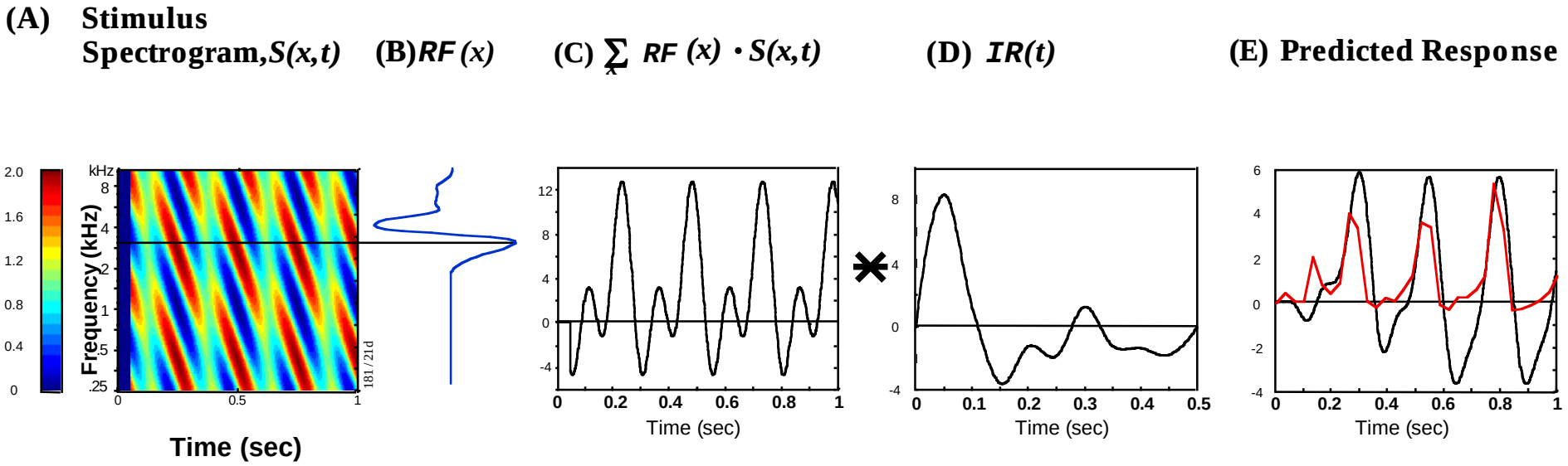


Impulse Response Function

Linearity of responses in the Auditory Cortex

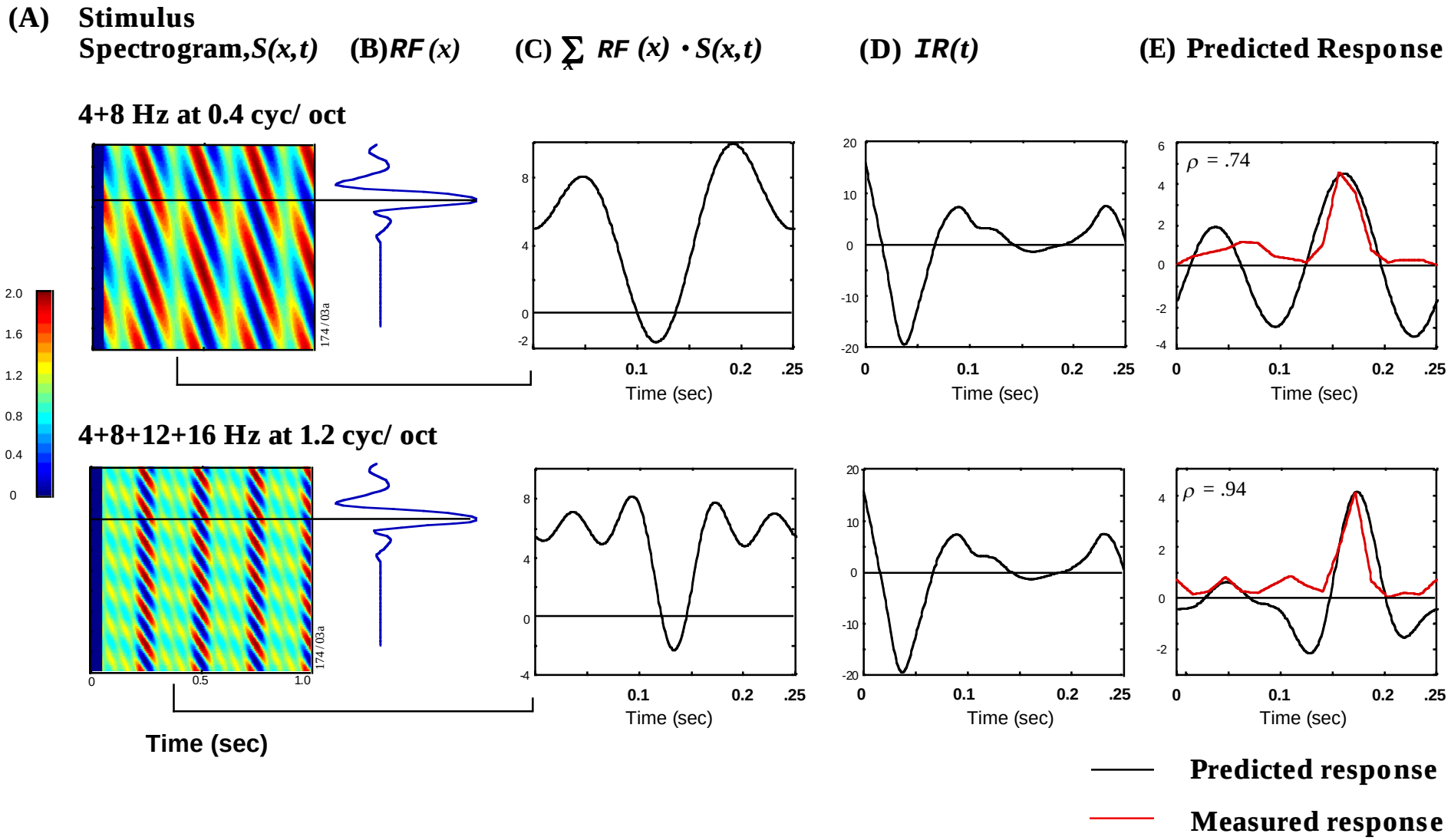
AI and AAF display similar characteristics

Anterior Field:

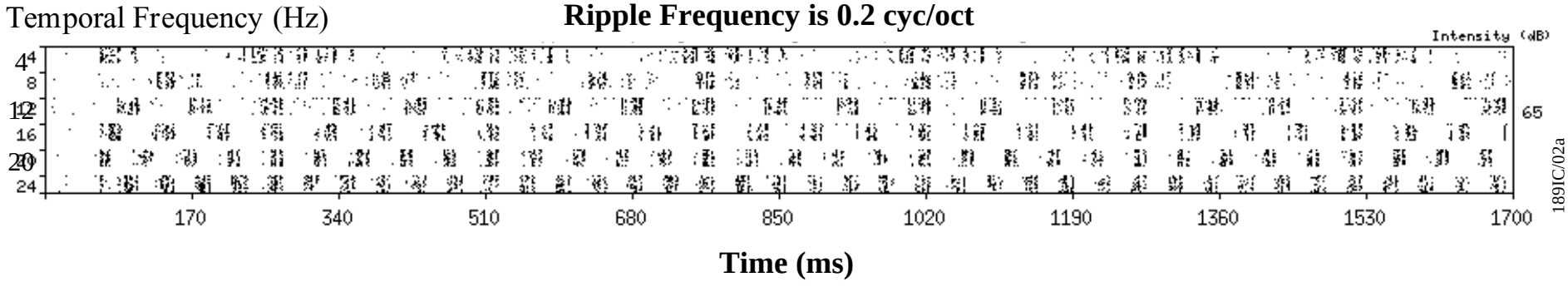


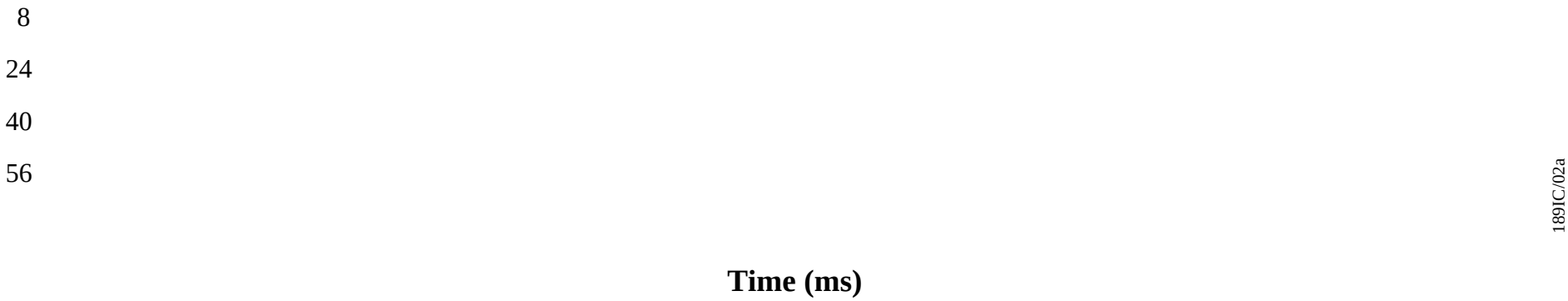
Predicting the Response to a Complex Stimulus

Primary Auditory Cortex:



Inferior Colliculus Responses





Ω = 0.2 cyc/oct

ω = 4 to 64 Hz

15 sweeps per ω

Summary

- Stationary and traveling ripples can be used to extract spectral and temporal properties of auditory cortical neurons.
- Linearity: Responses to a broad-band complex stimuli, decomposed into a linear combination of ripples, can be predicted by summing the neuronal responses to the individual ripples.
- Only Cortical neurons are selective to ripple frequencies; Collicular neurons are low-pass with respect to ripple frequencies.
- Therefore, AI and AAF neurons could perform a multi-scale analysis of spectral shape: the spectral profile is analyzed at different degrees of resolution by neurons with receptive fields of different best frequencies, bandwidths and asymmetries.

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